MODELING PERFORMANCE OF SOIL VAPOR EXTRACTION SYSTEMS

EAD used measured field data from a soil vapor extraction (SVE) system installed at the Twin Cities Army Ammunition Plant (TCAAP) to develop a computer model. Computer programs that model the processes underlying SVE systems must use complex, three-phase flow and transport codes that require significant computer resources and are typically run on a supercomputer. EAD is evaluating the T2VOC research code to determine if it can be used to develop an engineering approach to SVE design and operation. If the approach is successful, the model will be used to produce design and operational guidelines that can be applied to general SVE installations.

PROBLEM/OPPORTUNITY

SVE systems are used to remove contaminants from the unsaturated or vadose zone. In the system, vacuum is applied to a series of wells to draw air through the subsurface. The air volatilizes the volatile organic compound (VOC) contaminants, which then move with the air and are extracted and treated at the well head.

Design and operation of SVE systems requires models of the subsurface that include all the physical processes that can significantly affect performance. Guidelines on how much vacuum to apply, how to space the wells, and when to turn off the SVE systems are needed. Of particular interest is understanding when SVE system operation should be modified or ended as contaminants are removed.

Modeling these systems is difficult. The movement of water, air, and a VOC need to be modeled, as do phase transitions (for example, a VOC may dissolve into the water phase, sorb onto soil solids in the solid phase, or volatilize into the gas phase). The equations that describe these processes are highly nonlinear and difficult to solve. Subsurface geology can be complex and variable, and models must provide the needed resolution, which results in large numbers of simultaneous equations. These factors combine to make modeling of SVE processes a research task. EAD is evaluating whether various codes can be used for engineering applications.

APPROACH

EAD is evaluating T2VOC, a three-dimensional code developed and used for subsurface research, to determine if it can be used to produce engineering design and operational guidelines. The code was developed by Lawrence Berkeley Laboratory to model soil vapor and steam extraction systems. It is one of the most advanced codes available for working on multiphase, subsurface problems, and it has a range of numeric routines that incorporate the latest in equation solver research. However, the application of the code, even with these advances, takes significant computer resources.

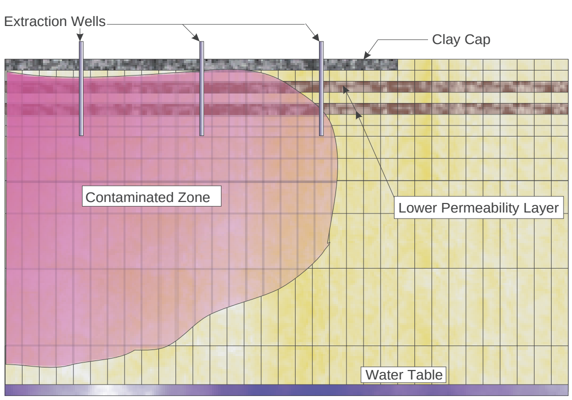
In evaluating the applicability of T2VOC, EAD has developed a three-dimensional heterogeneous model of a three-well segment of the TCAAP SVE system. It has also developed special visualization routines and modified the T2VOC code to interface with these routines. In addition, EAD modified the time stepping routines in the T2VOC code to more efficiently solve the SVE problem and to handle larger models.

EAD is using the modified T2VOC and visualization tools to evaluate a number of different parameters that affect the performance of SVE systems. The impacts of heterogeneity, soil properties, VOC properties, and other parameters are being evaluated. Field data were used for control, to ensure that the model's processes match field processes. EAD is also evaluating the effects of various pumping schedules on extraction efficiency.

Results

EAD's initial findings are consistent with experience and suggest that the success of SVE systems depends highly on the soil at the cleanup sites. In soils where air moves freely, such as sands, SVE systems provide an efficient cleanup solution. In tighter soils, such as clays, the systems are not as efficient and require longer pumping times and closer well spacings. These initial results provide a measure of confidence in the model.

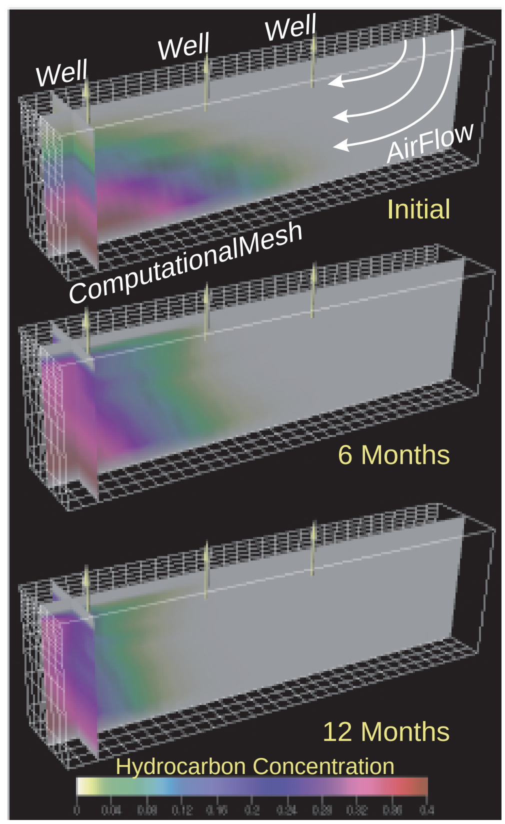
Soils with regions of lower permeability, such as clay seams, are problematic, since the air preferentially moves through the higher permeability sands and does not flush the VOCs from the tighter soils. These VOCs gradually diffuse into the looser soils and are swept to the extraction wells. Thus, the extraction wells show VOC contamination, but continued pumping is not efficient because of a contaminant "tail" that can last for long periods of time.



This vertical slice of the computational mesh used for the T2VOC model shows extraction wells, soil properties, and the contaminated area.

Status/Future

This research is ongoing. The goal is to provide guidance on what types of sites SVE systems can successfully address and recommendations on when to turn the systems off and how to operate the pumps. A second goal is to develop recommendations for modeling these systems. Until now, three-phase flow modeling has been employed only in research settings; however, new codes and machines are making these tools available for engineering applications and design. EAD is evaluating this research level code to determine if it can be used to develop an engineering approach for optimal SVE design that would not require the use of a full three-dimensional model. If this method is successful, EAD will provide guidance on when it is appropriate to use SVE systems and how to design an extraction system optimally without requiring long and costly three-dimensional simulation.



Model results for a year of pumping show how the air sweeps in from right to left while the wells draw contaminants up and out of the system.

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